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Renewable and non-renewable energy status in Iran: Art of know-how and technology-gaps

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ABSTRACT

This paper reviews the present energy status in Islamic Republic of Iran with an emphasis on utilization of environmentally friendly energy resources. The paper reveals the huge energy losses due to technological gaps and absence of relevant art of know-how in conventional energy industries. It also includes some critical issues effecting the efficient operation of Renewable Energy Converting Systems (RECS) having specific site and climate dependency. The environmentally friendly scaled energy balance presented in this paper is self explaining for energy policy makers to achieve a suitable scenario based on various positions of scale pointer which may alter depending on implementation level of advanced technologies and relevant art of know-how.

The paper, besides being informative in achieving optimal energy prospects in Iran, also provides useful quid lines to energy planners not only at home but also in other Asian/Middle Eastern countries having similar alternative energy scenarios.

Contents

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1. Introduction

Today, the sustainable realistic development and growth is one which does not have diverse effects on environment and should not damage the natural resources. Iran is the second Middle Eastern country with respect to enjoying various energy resources. Besides abundant conventional sources of energy, like oil and natural gas, the country is blessed with large renewable energy resources such as solar, wind, geothermal, hydro, etc. Moreover, life of oil reserves are limited and the share of next generation must be considered so that they may have better option to utilize these badly treated treasures. That is why, based on policy of minimum extraction from fossil fuels and also copping with the technological progress taking into account the environmental considerations, the government in its each five yearly development plans does emphasize on large utilizations of alternative energy resources in Iran. In this context, the first author presented the prospects of nuclear power plants for sustainable energy development in Iran [1]. Now, at the present paper, the authors focus on the overall energy status, taking into account the significant roll of all kind of available sources of energy in Iran, both conventional and non-conventional ones. Furthermore, the emphasis on affects of technological gaps in conventional energy industries and particularly those involved with RECS are other contributions of the present paper. For instance as a supporting example, some site and climate issues which alter the performance of RECS are highlighted in this paper using relevant data based on extensive field experience gained from the operative wind farms in Iran.

The latest energy balance sheet indicates that there is a balance between supply and demand of electric power in Iran. However, in spite of such achievements in power generations which are mainly based on conventional energy resources, efforts are extensively carried out towards new achievements in utilizing the renewable energies, nuclear power, fusion, etc. Based on such energy mixed policies and taking the environmental safety as a referring scale, one can opt for various environmental friendly energy balances with different positions of scale pointer as per preferred contributive share of each source of energy on both sides of the balance.

2. Conventional energy: a review

There is no coordination between discovery of oil reserves and the consumption factor. Population growth parallel with economical development, having low GDP, rise energy requirements as well as energy intensity. The main conventional energy resources in Iran are; oil, natural gas, coal and some noncommercial energies. The following brief information regarding each source of energy indicates the complexity of energy planning which is dependent on each energy source as an individual variant.

2.1. Oil

The affordable oil reserves in Iran during 2008 are estimated to be 137.01 billion barrels. Iran's economy is mainly dependent on export of oil. The local consumption of oil is around 1.5 million barrels per day. The extraction from oil reserves is mainly related to the quantity of oil exports that turns out to be 2.36 million barrels per day during 2008 [4]. The present policy is entirely based on the conservation of oil reserves for better utilization against non-calculative use of such great national treasure both economical and political. However, considering the increasing rate of the local consumptions, the present affordable oil reserves will last no more than 84 years from now.

2.2. Natural gas

Iran is one of the richest countries in natural gas resources. The affordable gas reserves estimated in 2008 was around 29,600 billion cubic meters which is around 16% of the total world's reserves [4]. The gas utilization mainly covers the local domestic, industries and power plants consumptions via widely spread pipe lines throughout the country. Further in future scenario, besides boosting the export programs, the extension of pip lines are to be extended even to the most inferior parts of the country. Under such supply and demand potentials, the arguments and doubts regarding the possibility of either to be able to maintain the balance between supply and demand or not is very much valid. In fact at present, during the peak demand times (winters), Iran Gas Company is unable to manage the required supply. Moreover, only on basis of 2007 local consumptions, the life span of natural gas reserves is estimated to be around 166 years [3]. That is why the conservatives are against the export of gas before securing the fulfillments of local demands and instead insist on its storage by injecting it into the oil wells.

2.3. Coal

The capacity of affordable coal mines in Iran is estimated to be 1.2 billion tons, while the known mines are of capacity of 11–14 billion tons. These mines are located in much deep ground layers and the extraction process becomes quite expensive. There are 166 coal mines in Iran out of which 102 are operative, 54 not operative and 10 under preparation. Among these mines only 29 mines are owned by the government and the rest are owned by private sectors. Presently, the total extracted coal from these mines during 2008 was around 2.7 million tones. Hence, only around 2% of the coal mines is extracted which is mainly consumed by the industries [4]. In view of the above facts and also the environmental considerations, it seems, there is no further plan to utilize coal for electric power generation in Iran.

2.4. Non-commercial energies

These include the energies obtained from animal wastes, forest wood, bushes and other motes and stalks. Such energies cover more than 40% of domestic requirements (heating & cooking) of the rural population in Iran which equals 0.5% of total national domestic requirements. For instance the quantity of wood cut during 2008, only from northern forests turns out to be around 937,000 cubic meters [4]. Iran is an agricultural country and more than 30% of the populations live in villages. In order to boost agricultural products, improve living standards and encourage local handicrafts, the supply of electricity to rural areas is an essential task. Therefore implementation of renewable energy programs in rural areas can substantially provide their energy requirements.

3. Renewable energy reviews

Although fusion energy is certainly an important and fatal option, off course with great technological challenges facing mankind, but at the same time the development of solar energy systems and technologies are much easier to achieve. Solar energy along with hydro, wind, biogas, biomass, geothermal, wave and ocean energy are environmentally clean and non problematic sources of energy and due to their technical simplicity are certainly an interesting option left for man. By 2030, the renewable energies are projected to contribute 29% of power generation and 7% of transport fuels [5]. While attainable, this objective requires strong political and financial supports as well as immediate action by all governments. Results of study concerning the possible renewable

energy utilization in Iran show that a target of 20,000 MW is feasible in year 2025. Off course, 10 percent renewable energy contribution in only 15 years needs determination, data acquisition, technology achievements and planning. For this purpose crucial elements of a national program should be defined. These elements are in forms of three kinds of projects:

- Fundamental projects leading to detailed analyses of renewable energy data, site selection, techno-economical analyses and feasibility studies concerning the availability and difficulties of renewable energy conversion technologies.
- R&D programs and prototype projects for better understanding of technical achievements and efficiency improvement. These projects are defined regarding the state of art technology, national and international bodies' recommendations.
- Joint venture cooperation and research programs at regional and international levels intended to reach further technical improvements and technology transfer.

As it can be seen these projects are inter-connected and therefore the precise definition and sequences are very important. The results of these projects in less than 4 years are the essential elements for a policy making and a national development program. Obviously the above referenced results will determine priority, economic viability, future investments and the preferred contributive share of each source of energies.

The abundant available oil and gas reserves in Iran plus the cost factor probably were the main superficial and improvident excuses that Iran did not deplore its vast available renewable energy resources much earlier. However, some activities limited to scattered research programs and some prototype projects related to all fields of renewable energies have been pursued by various departments in Iran. But here after in this paper, only those alternative energies which have a considerable contributive share in Iran's energy scenarios are referred and discussed.

3.1. Solar energy

Iran in spite of being very rich in conventional energies has also great potential for large-scale application of solar energy systems. The country is covered with 60% barren land with maximum solar radiations. The annual average sun radiation is 20–30 MJ/m^2 in a day. The sunny hours during four seasons are 700 h during spring, 1050 h during summer, 830 h during autumn and 500 h during winter. The amount of solar energy received by 15,510 km^2 (<1% of land) in Iran cannot only fulfill the present annual energy requirements at home but it can as an equal amount be exported to other countries too. However, developing solar energy systems will take place over decades, that is, extensive penetration of solar energy into energy markets will not happen quickly for several reasons, such as time lag for technology development, development of large manufacturing industry and limitations of total capital investment.

The Iranian government encourages the individuals and private sectors to use/make the solar water heaters and photovoltaic converting systems by granting substantial subsidies. The outcomes of these incentives are thousands of solar water heaters installed all over the sunny areas of the country in recent years.

The program to install several solar energy systems in Iran will enlighten the deprived people in rural area throughout the country. Presently, besides thousands of small direct current individual photovoltaic units which are used in roads, highways, parks and communications, there are only a few photovoltaic electric power generating units with a total installed capacity of around 150 kW. There is also a 250 kW solar thermal power generating system installed in Shiraz. However, such scattered achievements may be attractive but not enough and certainly they should not be counted as outcome of a purposeful national strategic energy plan.

3.2. Wind energy

Wind energy as an exploitable resource is now a reality and not a dream as related by hundreds of rotating wind turbines installed in the length and breathe of many countries, generating electricity and feeding power into the local/national grids.

Persians were the first people to install the first wind mills some 200 years B.C. Still, some of those historic wind mills are still operating in rural areas of Khorasan province. Iran is blessed with four season climate and besides having vast deserts; it is also mostly a mountainous land which has the Caspian Sea on its north and Persian Gulf and Oman Sea on its southern part. These climatic and geographic conditions indicate the availability of sites with high locally wind energy potentials. Moreover the country is also blessed with various tropical wind flows. These are central flow from Central Asia during winters and Indian Ocean during summers, western flow from Atlantic Ocean and Mediterranean Sea during winters and the north western flow during summers. Fortunately as per the wind power classification made by the U.S. Department of Energy, starting from class 1 to 7, based on values of wind power density (W/m^2) where class 1 is for 50–200 W/m^2 and finally class 7 indicates the range of 800–2000 W/m^2, most of the windy sites in Iran are of class 7 category. According to the recent wind energy survey in 45 suitable Iranian sites, the wind energy potential is estimated to be 6500 MW, taking the average efficiency of 33% [2]. This is against many available unique windy sites in the country with an average annual efficiency of 60–70% and if accurately selected the wind energy derived can practically be much more than the present 6500 MW (estimated statistically). The availability of such vast wind energy potential in Iran insures the possibilities of establishing large wind farms feeding large amount of power to the national grid as well as autonomous units for isolated loads. Presently, the capacity of installed wind farms in Iran is approaching 75 MW, mainly located at two northern sites, Manjil and Roodbar wind farms, where the converted energy is fed to the local grid. These wind farms are planned to be further enhanced up to 90 MW. Moreover, installation of another 60 MW wind farm is also under consideration [2]. The capacity factor obtained by the above mentioned operative wind farms is more than 60%. It is quite obvious that with such unique availability of wind energy the present amount of its utilization is far behind the deserved quantity and if correctly utilized Iran will be one of the top users of wind energy. Besides the wind electric systems, there are many multi-blade turbines, pumping water mechanically for irrigation purposes throughout the country.

It is essential that Iran should not fall behind in this new field of technology. However, it is a far journey in order to fill up the already created technology-gaps and to utilize the large wind energy potentials. Therefore, to augment power generation in Iran, all efforts have to be made to bridge the technological gaps and achieve self reliance in wind energy exploitation too.

3.3. Hydro power

Presently, there are 42 operative hydro power plants with total installed capacity of 7672.5 MW and other ones with total capacity of 6650 MW are also under construction. Out of the operative plants, number of big, medium, small and mini/macro plants are 6, 12, 12 and 12 respectively. The big hydro plants, ranging above 100 MW, cover more than 90% of the present installed capacity. Further, it is planed to construct more big and medium hydro units, enhancing the present capacity behind 25,000 MW. The annual

quantity of power generation from the hydro units depends on amount of water falls. For instance, in 2007 more than 18,000 GWh electricity was fed to national grids while this amount was reduced by 72% in 2008 due to droughts [3] and [4]. Besides power generation the water storage behind huge dams also solves the irrigation problems in many parts of the country.

As mentioned before, Iran is mostly covered by mountains, therefore, besides having various big and small rivers, there are obviously many water streams which either go waste or terminate at rivers and then connect to sea. Hence, thousands of small and Mini/Macro hydro systems can easily be installed through these streams which can provide locally needed electricity or to be fed to local grids. Presently, there are only 12 small hydro power systems with a total installed capacity of 46.5 MW and 12 Mini/Macro hydro systems with a total capacity of around 2.9 MW [4]. Unfortunately, the available hydro potential from Mini/Macro systems is not yet accurately estimated and these vast potentials of hydro power, like other renewable energies, are not effectively utilized and are even deprived of any further extensive planning. The machineries and know-how of such systems are simple and can locally be manufactured to the extend that, if the planning is focused on this field the power derived will be amazing and Iran like China can become one of the top utilizer of such hydro potentials, making the country capable of even exporting this technology to neighboring countries.

3.4. Geothermal energy

Iran is located on the global geothermal belt. This is evident by many warm water streams, volcanoes and regular ground movements. There are four main locations with the total area of more than 31,000 km^2 which contain great amount of geothermal potentials. The government has already approved the installation of a 50 MW geothermal power plant in Meshkinshahr province. The initial estimation indicates the possibility of deriving 200 MW geothermal power from the sites located in the above mentioned province [2]. There are other suitable locations which are under investigation for site selection and power capacity estimations.

3.5. Biogas plants

The importance of the biogas is its site independence unlike all other renewable energies which are very much site specific. Domestic and industrial sewage/waste, animal dung/waste, 80% (valid % in Iran) of garbage and left over of agricultural products are the main sources of biogas energy. All these matters are also great sources of pollution and carriers of many infectious diseases in and around every city and village which may become epidemic mainly during hot seasons. These are the serious problems mostly faced by the third world countries. The renewable energy resources are converted by the non-pollution-making systems except the biogas plants which convert the pollution source to energy and non polluted useful matters such as fresh fertilizer and water for irrigation. Hence, the focus is not on the power production or its quantity and in order to have a healthy leaving environment the biogas systems are the best options. The future scenario for this source of energy is aimed at producing total of 10 MW power from garbage/waste of a couple of major towns/cities with population of above 250,000 in Iran. Presently a pilot prototype project is operative in Saveh, south west of Tehran.

4. Nuclear energy

As mentioned earlier, according to the present policies, the diversification of energy generation by various energy sources is a secured method of planning national energy policy in which nuclear power plants hold a substantial unavoidable share. Before Islamic revolution in Iran, the total capacity of nuclear power plant was aimed at 23,000 MW and the Bushehr 1000 MW nuclear power plant was the first power plant of the same program. In spite of all odds, the need for peaceful nuclear energy is specifically emphasized in each development plan. In view of economical growth of 8%, the government is determined to enhance the nuclear power plants to 20,000 MW in next 30 years [1].

5. Fusion energy

Debates about whether or not to invest heavily in nuclear fusion as a future energy option have been made within the context of energy technology development strategies. However, there has been a growing demand for studies to assess nuclear fusion so that the potential of the technology can be realized [6]. Iran, after Japan, Europe, USA and Russia is one of the first Asian countries to enter the state of research and development of nuclear fusion. This task is undertaken by the Faculty of Plasma Physics and Nuclear Fusion in Atomic Energy Organization of Iran since 1980. The activities of this faculty are divided into three groups of Magnetic Confinement Fusion, Inertia Confinement Fusion and Applied Plasma Physics. These groups consist of number of scientists engaged with the world's latest achievements and R&D in each relevant field. The research has been started using theta pinch machine and continued by small size tokomaks "Alvand" and "Damavand" and also Plasma Focus "Dena".

Fortunately, the government has recently decided to continue peaceful research in these fields very widely and extensively. In this context, the two yearly program of feasibility studies of a national project to design an experimental fusion reactor have already started in February 2010. It is expected that this project will join to other similar international projects and be able to have its contributions towards commercialization of fusion energy in near future.

6. Electric power generation and demand

Iran with a population of 72.6 millions and area of 1,648,000 km^2 is capable of annually (2008) generating 2955 kWh electricity per head with an average annual growth of around 6%. Excluding some 5000 villages at rural areas with no approach to the national grid, presently more than 99% of Iranian homes are provided with electric connections. The numbers of operative thermal, gas, combined cycle and hydro power generating stations in Iran, based on 2008 data, are 19, 32, 12 and 42 respectively with a total installed capacity of 53,000 MW. Fig. 1 depicts the contributive share of each type of power plant in

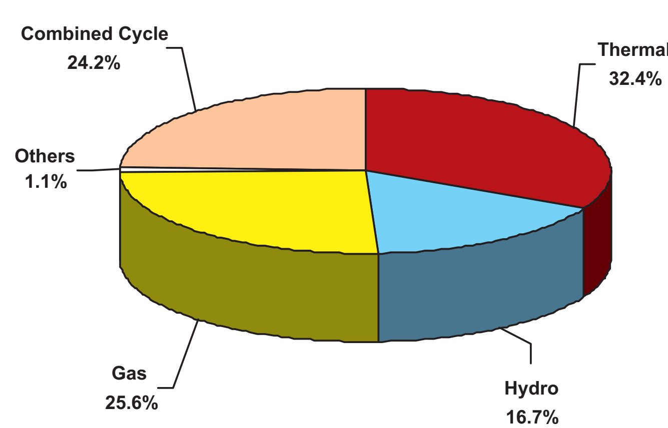


Fig. 1. Present contributive share of energy resources in electric power generation.

Table 1
Amount of pollutants (tons) and greenhouse gases emitted from burning fossil fuels in Iran during 2007.

Fuels	NOx	SO2	SO3	CO	SPM	CO2	CH4	N2O
Liquid gas	1925	369	–	14,272	–	8,081,145	1122	44
Petrol	317,596	35,288	–	8,233,971	30,583	55,967,614	26,443	2562
Kerosene	3734	17,923	–	8525	–	19,446,284	811	162
Gas oil	607,460	535,992	6306	145,804	279,529	92,632,989	4481	7642
Fuel oil	131,339	814,387	8409	62	17,351	58,322,366	2148	429
Natural gas	283,701	745	–	15,521	24,078	245,452,905	6820	441
Refinery gas	*	*	*	*	*	4,360,136	85	8
Others	33,116	19,964	236	61,010	76,707	7,837,430	1090	233
Total	1,378,871	1,424,668	14,951	8,479,165	428,248	492,100,869	43,000	11,521

* Amount not accessible.

fulfilling the present electric power demand. The same published data show that the electric supply and demand in Iran is to some extend balanced [4]. On the other hand, considering the target of 8% economical growth and simultaneously an annual growth of 8% in electric demand, the electric power required in 2025 is expected to reach as high as 195,000 MW. The same forecast based on 6% economical growth shows around 150,000 MW electric power requirements in 2025 [1]. In that case if the purposed share of electric power to be derived from environmental friendly energy resources is not actualized then more than 80% of above electric power would be generated by conventional energy resources and mainly by combined cycle power plants.

7. Affects of technology-gaps

7.1. In conventional energy sectors

A simple review of present energy industries in Iran will reveal that a huge amount of energy is lost mainly due to; non-effective operation, absence of relevant art of know-how and advanced technologies. These annual energy losses are up to the extend that even partially controlled they not only cover a substantial part of annual energy demand but will also help in eliminating an abundant amount of pollutants and the greenhouse gases caused by burning their equivalents of fossil fuels. Table 1 shows the amount of pollutants and greenhouse gases from burning fossil fuels in Iran during 2007. It is evident that more than 24% of CO_2 emission is due to fossil fuel combustion in thermal power plants. Table 2 shows the amount of energy losses in various conventional energy sectors in Million Barrels Oil Equivalent (MBOE) including the percentage share of emitted pollutants from the same energy sector during 2007. As observed the total energy losses during the refining and conversion process are 425.40 MBOE i.e. 27% and 37% of primary supply and final consumption respectively. These are enough reasons for having energy intensity of 1.99 and per head energy consumption of 1.9 tons of oil equivalent for a population of 72.6 millions.

One of the most energy consuming as well as polluting sector in Iran is the transportation sector by which 258.47 MBOE is consumed during 2007. The share of petrol consumption is around 128 MBOE that turns out to be around 64.5 million litters per day, Out of which 38.22 MBOE was to be imported during the same period. However before the implementation of petrol rationing program in 2007 the daily consumption of petrol had reached as high as 85 million litters per day. The amount of energy losses in this sector is not accurately scalable and depends to the level of advanced technologies used in various vehicles and car industries. For instance, the average distance coverage per litter of petrol is presently 10 km. In case the vehicle's performance is improved to the standard level of 20 km per litter then one can estimate the result by referring to the above information. In that case, another energy loss of 130 MBOE would be added to the total energy losses of Table 2 as transportation losses too. Finally, if each cause of the referred energy losses is diagnosed and gradually eliminated there can be a considerable change in country's energy planning and it will also help to reach to an optimal environmental friendly energy balance.

In view of the above facts, if a sustainable technology improvement program plus a targeted strategy to substitute/eliminate the retired industries is carried out then the country's long term energy demand can be fulfilled by alternative energy resources (clean energies) including nuclear and hydro power without any further substantial development of fossil fuel power plants. The implementation of relevant art of know-how and programs to improve the technological gaps should mainly focus on those energy sectors having higher losses like transportations, power plants and old refineries. It is understood that in the present competitive market and the increasing energy costs the consumer sectors will have no alternative to adopt the terms and conditions dictated by energy conservation laws. Therefore the authorities should mainly focus on improving the performance of energy sectors at the supply end. For example, if the present 34% efficiency of power plants is annually improved by 6% to gradually reach to the possible range of 65%, the present capacity of electric power supply will suffix the demand of next 5 years. Such sustainable technology improvements will result in an environmental friendly power generation, as predicted in Fig. 2. This would be quite different from the prevailing power supply planning which results in more depletion of fossil fuels and consequently more atmospheric pollutants.

7.2. In utilization of renewable energies

It is understood that most of the present technology-gaps are due to some wrongly planned initial establishments which are mostly evident in conventional energy industries. The bitter

Table 2
Energy losses (MBOE) in various energy sectors and their percentage share of emitted pollutants.

Energy sectors	Losses (MBOE)	NO_x (%)	SO_2 (%)	SO_3 (%)	CO (%)	SPM (%)	CO_2 (%)	CH_4 (%)	N_2O (%)
Refineries	198.97	*	*	*	*	*	4.6	1.09	0.5
Power plants	201.4	3.15	32.84	20.8	*	5.95	24.41	6.98	3.97
Power distribution	25.02	*	*	*	*	*	*	*	*
Transportation	*	61.26	28.12	30.07	98.52	77.72	23.46	75.55	48.44
Total	425.39								

* Amount not accessible.

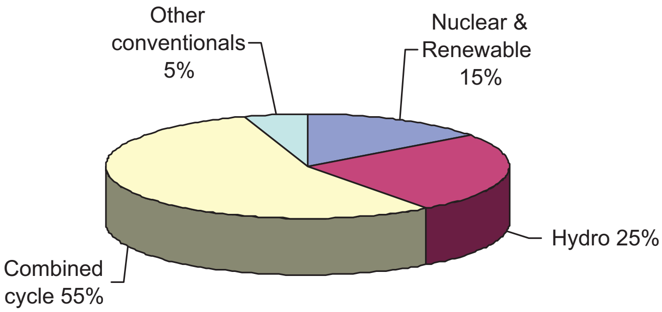


Fig. 2. Predicted environmental friendly share of energy resources in power generation in 2025.

experiences of conventional energy industries should be avoided so that the same fundamental mistakes are not repeated in the process of initial planning and development of alternative energies. Now, the main question is not "why" to opt for alternative energy systems but how to utilize them successfully? The efficiency of a renewable energy converting system, irrespective of its source, is effectively climate and site dependent. For instance, in a wind farm or in a solar thermal power plant, consisting of a number of wind turbines or solar collectors, performance of each individual unit differs from one to another because a small variation in wind speed or in solar absorption affects the quantity of derived power. Hence, the trick of know-how is how to plan such power plants to minimize this non homogenous performance, taking into account the specific conditions of each locate and corner of the site. On the contrary, one can import a few systems or at most import the technology and/or make the reverse engineering of the same and install them in selected sites, but to make them operate successfully against all odds requires tremendous technological and organizational skills which till date are mostly ignored in all such installed plants. These are also the main causes of the present prevailing low profile of the RECS in Iran. Moreover, the process of substituting a prevailing conventional system by a new updated technology, besides problems of technical know-how limitations, also bears a social anti-habitude resistance. The worst situation arises when by any reasons such systems become unsuccessful then to defend their superiority will be a tougher task than before. Hence, such important factors are to be considered as top priorities before and during the site selection, planning and even design of each individual unit. For example, if the weather dependent supply of wind power were to be integrated successfully into already existing supply structures and those which are to be developed, besides the energy supply, the influences on the grids as well as on the consumers of electricity are becoming more and more important. On the contrary the adverse effects of a poor grid on the wind farms are of great concern which in some sites may even reverse the advantage of having a regular high wind speed. That is why, the practical efficiency of Manjil wind farm does not exceed behind 30% while the site is as efficient as 60%. Presenting the analytical cum practical studies regarding such problems are not within the scope of this paper and are already published [7–9]. However, in order to emphasize on importance of such essential issues, an extensive field investigation is undertaken in the Iranian wind farms. Further, as a sample case, the data concerning the statistic events during month of August (2009) in the present bulk operative Iranian wind farm "Manjil" is highlighted in Table 3. The field observations show similar non-homogenous working of units in all wind farms throughout the year. It is even to be stated that the same working phenomenon was also observed by the first author in one of the largest Indian wind farm "Lamba" too. These data clearly indicate that the number of occurrence of various events like higher limit of wind speed, grid abnormalities, stopping the wind turbine generators and their duration considerably varies from one unit/location to another. These variations are not the same throughout the year and may alter from month to another month. It is also observed that the wind speed is not similar throughout a wind farm and varies within range of 1–3 m/s.

Similar to wind farms the same observation as set in Table 3 can be true for other multi units renewable energy power plants, like Mini/Macro hydro, solar, wave, etc., feeding collective powers to local grid.

8. Optimal energy balance

What we understand from words "energy balance" is nothing but a balance between supply and demand of energy. What goes wrong with our environment during fulfillment of energy balance? Is the process of achieving this balance sustainable and environmentally friendly? What is the optimal energy balance? These are the ignored questions which are threatening the safety of all living hoods on earth!

Presently, there is an unstable balance between demand and supply of energy in Iran. The demand includes both domestic consumption as well as government's commitments to supply natural gas to some neighboring countries. The above mentioned balance is believed to be unstable in a sense that if under unexpected circumstances there is an increase in domestic

Table 3
Sample of non-homogenous performance of RECS in Manjil wind farm during August 2009.

No. WTG	Wind speed		Grid frequency		Grid voltage		Mechanical cause		Manual stop		Remote stop	
	No. events	Duration (h)	No. events	Duration (h)	No. events	Duration (h)	No. events	Duration (h)	No. events	Duration (h)	No. events	Duration (h)
1	4	6.57	9	3.66	–	–	1	4.98	7	0.22	–	–
2	5	28.21	5	3.17	1	0.03	3	4.94	6	0.38	2	0.02
3	–	–	5	2.91	2	0.15	–	–	5	0.17	1	0.01
4	–	–	5	3.19	1	12.56	1	0.52	5	0.17	–	–
5	4	15.40	5	3.19	–	–	3	4.04	7	0.93	–	–
6	11	37.08	5	3.19	–	–	4	27.48	5	0.17	–	–
7	3	11.35	4	3.18	4	13.01	–	–	6	0.30	–	–
8	1	0.01	4	3.18	–	–	–	–	5	0.18	–	–
9	1	1.53	4	3.15	1	0.57	1	0.10	5	0.17	–	–
10	–	–	4	3.18	–	–	6	15.74	5	0.18	–	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
18	–	–	4	3.02	7	11.57	5	12.95	9	0.73	–	–
19	40	157.72	3	3.00	1	0.02	2	5.85	5	0.17	–	–
.	.	.	.	.	.	.	.	.	.	.	.	.

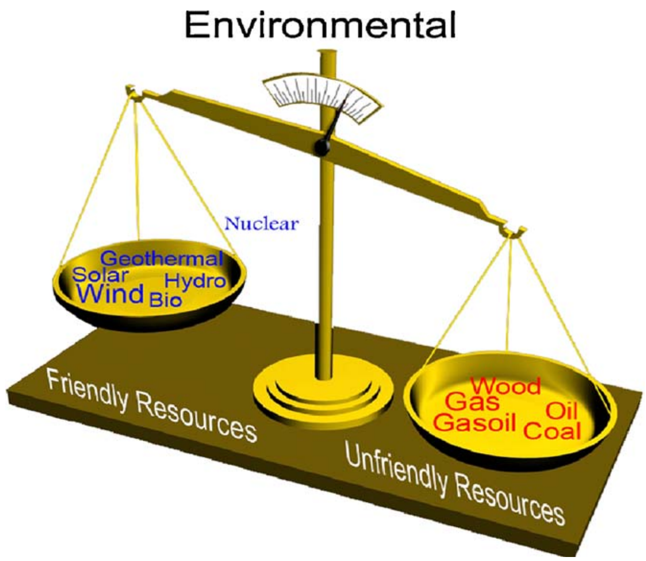


Fig. 3. Environmental friendly scaled energy balance.

demands, mostly occurring during winters, having peaks in gas demands and during summers with highest peaks in electricity demands, then due to supply shortage, the rationing scheme of gas and electricity would be implemented throughout the country. Moreover the present energy demand is mostly (99%) supplied by the fossil fuels which are surly among environmentally unfriendly sources of energy.

As another scenario, if the environmental safety becomes the referring scale to opt for preferred energy resources and their utilization level, then the setting of energy balance will entirely have a different shape as depicted in Fig. 3. As it is shown, the present trend of utilizing energy resources in Iran is environmentally unfriendly. This trend should definitely be altered as much as possible towards utilization of friendly energy resources such that the present instability of balance be reversed in favour of environmentally friendly resources side. Due to controversies around nuclear power, to be environmentally friendly or not, the nuclear energy is kept outside the balance but however as compared with fossil fuels, it is preferred to be located at environmentally friendly side of the balance as shown in Fig. 3. It is worth mentioning that nuclear power has been excluded from Kyoto protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI) as an eligible technology [10]. Taking into account the vast availabilities of renewable energy resources in Iran the optimal energy balance will be achieved when besides nuclear energy the maximum amount of power are preferably derived from the solar, wind, hydro, geothermal, biogas energy resources respectively. The more utilization of environmentally friendly resources will contribute to less CO_2 release to atmosphere.

9. Conclusions and suggestions

The conventional energy systems are ecologically problematic and must be replaced by clean alternative energy systems. The life of fossil fuels is limited and the policy to burn them for their heat should be replaced by programs to save/utilize them towards achieving a sustainable development.

Irrespective of environmental hazards, considering the target of 8% economical growth as well as 8% annual power demand growth in Iran, the present affordable conventional energy resources will not suffix the domestic energy demand in 2030.

The huge amount of annual (2007) energy losses i.e. 13% by refineries, 8% by transportation and 15% by power plants and transmissions are mainly due to absence of advanced technologies and relevant art of know-how. The urgent increasing efforts are needed to minimize these losses by introducing the relevant technologies and art of know-how in all related energy sectors.

Presently, the balance between demand and supply of energy in Iran is not sustainable and environmental friendly. If the environmental affects become the reference to determine the contributive share of each energy resource, there will be tremendous change in the utilized amount of energy resources. This change will obviously dictate to reduce the share of conventional energies against that of non conventional energy resources.

Countries like Iran with abundant oil and gas reserves should not only rely on these resources and with no further delay should adopt a comprehensive mix energy policy and must plan for the development of all kind of alternative sources of energy. In order to avoid future energy crises, a secured energy prospect should clearly determine the short, medium and long term contributive share of each source of energy both conventional and non-conventional ones.

Meanwhile the process of such substitution is gradual and hard task, due to lack of recognition of the external cost of conventional energy use. This fact must be considered in microeconomic decision making. However it is noticed that economic availability and capital constraints are the most important factors in any energy substitution program. Therefore, at first stage every alternative energy resources must be carefully examined and their potential and energy intensity for all locations should be determined.

As discussed in the paper, only in the electric power sector, the electric power demand in Iran is expected to approach near 200,000 MW in 2030, while the same demand is presently about 50,000 MW, 80% of which is generated by fossil fuels. It is obvious that the fossil fuel reserves will not cover the same percentage in 2030. Hence, the policy of boosting utilization of alternative energy resources like Nuclear power, solar energy, wind energy, hydro power, etc. is an unavoidable task and all these affordable resources should be utilized effectively.

Various programs to deplore the alternative energy resources have already been started in Iran. Unfortunately, till date the effectiveness of policies for promoting power generation from these resources is not remarkable. For instance, the prospects of nuclear power plants for 2030 indicate a share of 15,000 MW power generations from nuclear energy but the Bushehr 1000 MW power plant has not yet been switched on [1]. Similarly, the scenario of utilization of renewable energies, have not been effectively pursued. A target of 20,000 MW power generations from renewable energy resources particularly from solar, wind and mini/macro hydro energy resources with unique affordable potentials in Iran is easily approachable by 2030.

The renewable energy policy approach is undoubtedly environmental friendly with no political strains and moreover their relevant technologies can easily be transferred and/or become domestic in a short period of time.

Further, it is vital to work for technical achievements. In other words, for implementation of an effective program and widespread application of renewable energy systems, essential elements of required technologies must be made domestic, taking into account all local specific dependant elements to increase the efficiency and minimize the non homogenous performance of collective RECS. For this reason research and development programs as well as joint venture projects leading to technology transfer as well as developing the domestic art of know-how will be the fundamental elements of a national renewable energy program.

Energy substitutions need determination, know-how, planning and last but not least capital investments. It is a duty of the international bodies to give proper supports for implementation of

alternative energy programs. Such developments need more technical break-through by increasing world wide technical cooperation and fair joint venture research programs.

Finally, fossil fuel subsides is a universal barrier to the development of renewable energy systems, and its gradual elimination is already started in Iran. Moreover, to encourage the investment by the privet sectors, the government is legally bound to buy the electricity generated by any RECS owned by Non-Government Organizations (NGOs).

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